

USING 3D VISUALISATION TO UNDERSTAND HUMAN ARTICULAR CARTILAGE DETERIORATION

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Abstract

Understanding complex systems within the human body presents a unique challenge for medical engineers and health practitioners. One significant issue is the ability to communicate their research findings to audiences with limited medical knowledge or understanding of the behaviour and composition of such structures. Much of what is known about the human body is currently communicated through abstract representations which include raw data sets, hand drawn illustrations or cellular automata. The development of 3D Computer Graphics Animation has provided a new medium for communicating these abstract concepts to audiences in new ways. This paper presents an approach for the visualisation of human articular cartilage deterioration using 3D Computer Graphics Animation. The animated outcome of this research introduces the complex interior structure of human cartilage to audiences with limited medical engineering knowledge.

Keywords: 3D Visualisation, 3D Animation, Design Principles, Strategies, Human Cartilage.

1 INTRODUCTION

3D Computer Graphics (CG) visualisation enables scientists working across fields such as medicine and biological engineering to improve our understanding of phenomena that is difficult to observe. Much of what is known about the human body is currently communicated through abstract representations including raw data sets, hand drawn illustrations or info graphics. The advent of progressive laboratory equipment and information systems is increasing the range and complexity of biological data. This is enabling scientists and biological engineers to illuminate our understanding of the human body. However, they are also seeking to address the problem of how to represent various data types meaningfully to allow this complex information to be readily interpreted and communicated to people from other fields [1]. Being predominantly concerned with understanding and demonstrating the major causes of arthritis and osteoarthritis in the human body, researchers from the Medical Engineering Faculty at Queensland University of Technology (QUT) are confronted by this problem.

Human articular cartilage is a complex biological structure composed of various components including cells, fibers, lipids and fluids. These all work together closely and interactively to achieve the function of this tissue. This paper presents the development of a short 3D animated visualisation of human articular cartilage based on data that was provided by the Medical Engineering Faculty at QUT. The objective of this animation is to introduce the complex interior structure of human cartilage to audiences with limited medical engineering knowledge and background. The animation explains the function of each component of human articular cartilage and covers the major causes of cartilage degradation which is a major symptom of arthritis and osteoarthritis.

2 BACKGROUND

2.1 Computer Visualisation

Over the last decade, computer graphic visualisations have come to play an increasingly important role in biological research and practice. 3D animation has improved the field of biological research through healthcare communication, consumer needs and education [2]. However, due to its time consuming process and associated cost of production, 3D CG animation was often not considered to be an effective method to visualise medical information. Instead it was considered sufficient to show images (photographs or digitised images) in the printed version of an article to illustrate a biological experimental result.

Intuitive and efficient visualisation is increasingly important at all intermediate steps in medical projects [3]. However, this technology was not widely used even though the advantage was obvious. One of the reasons is because 3D visualization techniques are computationally intensive. They were historically restricted to professional computer workstations, preventing widespread use [4]. However, recent advances in processing power and 3D graphics cards, along with inexpensive computer memory and hard drives has resulted in faster and cheaper production methods. 3D animation's ability to accurately, interactively and efficiently deliver information provides researchers the opportunity to communicate with other participants in new ways. However, a large amount of biology-related research findings and knowledge are still presented and communicated through traditional approaches such as hand drawn illustrations, data sets or info graphics. Human articular cartilage is one of these research areas requiring a new approach to better explain and understand its complex nature.

2.2 Articular Cartilage

Human and animal movement is facilitated by the contraction of muscles attached to joint bones. A soft, thin protective tissue called articular cartilage covers the surfaces of the skeletal joints. This 1-4mm thick tissue is a complex matrix composed of cells called chondrocytes, surrounded by a dense matrix of knitted collagen fibers, water bound proteoglycans and other small molecules and lipids. The collagen meshwork entraps the proteoglycans to form osmotic swelling, which maintains the function of this tissue. Research in this anatomical field demonstrates that the major cause of articular cartilage lesion is arthritis, where the predominant form is osteoarthritis, which generally causes pain, stiffening and a limitation of the joint function [5]. Osteoarthritis is characterised by roughening, splitting and wearing away of the cartilage surface. Because articular cartilage contains no blood vessels, lymph nodes or nerves to repair itself, the damage remains permanent. Cartilage is a highly resilient tissue capable of withstanding a lifetime of repetitive stress and sporadic impact, however, once damaged it is no longer capable of preventing direct bone-to-bone contact.

When cartilage is under pressure, the applied load is totally transferred into the cartilage matrix developing hydrostatic swelling and pore pressure. This pressure further distends the collagen meshwork creating an elastic deformation of its meshwork. It is an extremely complex procedure including fluid exudation, osmotic process and internal-external diffusion. Current experimental methods such as imaging and radiographic evaluation are extremely limited [6]. Researchers are not able to observe the dynamic movements and reaction of the components of cartilage when they are operating to resist applied pressure.

3 MATERIALS AND METHODS

3.1 Research Method

This is a practice-led research project that adopts the qualitative methods associated with reflective practice. That is, the research was initiated in practice and used the methods familiar to animation practice to develop the final research outcome in the form of a 3D animated artefact.

3.2 Materials

Data represented by the animated outcome was received from Professor Kunle Oloyede and Hayley Moody. Professor Kunle is the leader of the cartilage research team in QUT and Hayley is one of his PhD students. The original information they provided consisted of written cartilage thesis, several microscopic pictures and one visualisation model they did in 1994. Early in the project Professor Oloyede spent several hours explaining the structure and function of cartilage. This discussion resulted in many rough drawings on paper. These drawings proved crucial to developing an understanding of cartilage and the modelling process required of this project.

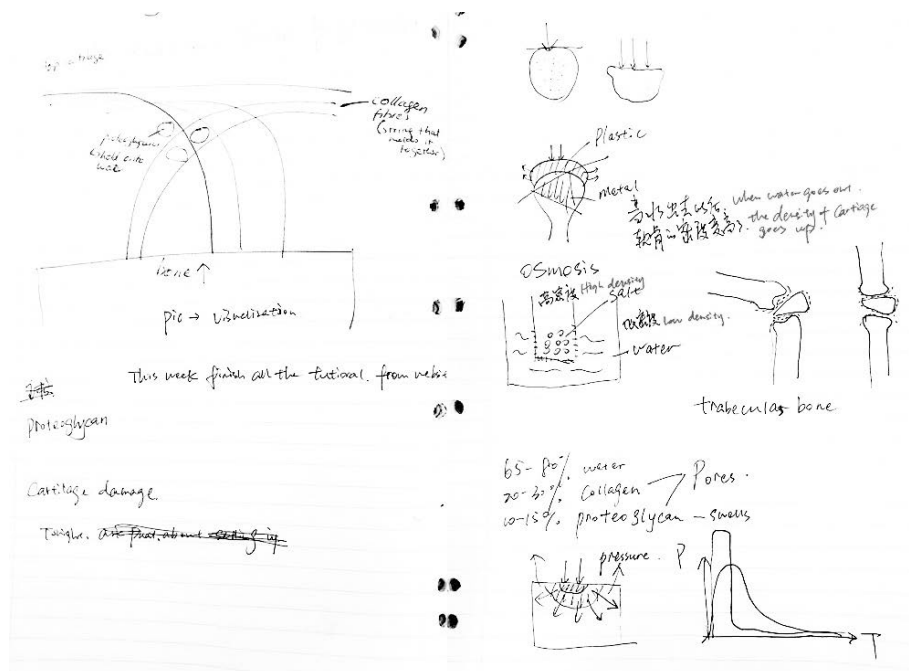


Figure 1: Rough drawings from early discussions with Professor Oloyede.

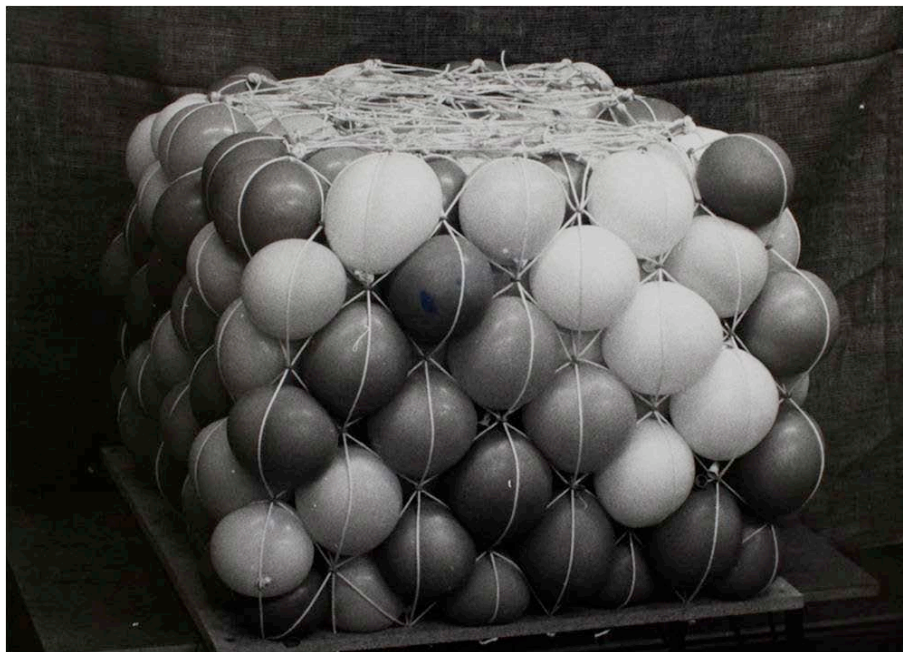


Figure 2: Physical visualisation model of human cartilage. [7]

The cartilage physical model of Broom and Marra [7] and elucidated by Professor Oloyede and Broom in 1994 [8] was another extremely important step in this practice. The approach featured above in figure 2 used water balls and string to simulate the components and function along the structure. The physical visualisation proved to be an effective approach to explaining the complex structure to others. However, it was anticipated that 3D CG animation could improve upon this further. Therefore this earlier physical model was used as a guide to visualising cartilage in the 3D CG medium.

3.3 Creative Process

The first step of this project was to evaluate which technical approach should be taken. Reviewing the structure of human cartilage and the function of each component resulted in the choice to use Autodesk Maya as the primary 3D animation tool. Maya provided a wide selection of industry standard modelling and animation tools capable of creating the complex imagery required for this project. The

production process was divided into three phases including pre-visualisation, storyboard and animation.

The cartilage physical model mentioned above provided support towards understanding the function of each component of cartilage. It provided a foundation for the development of an early 3D model, which enabled us to finalise the animation script and limit the potential for technical problems later in the development life cycle.

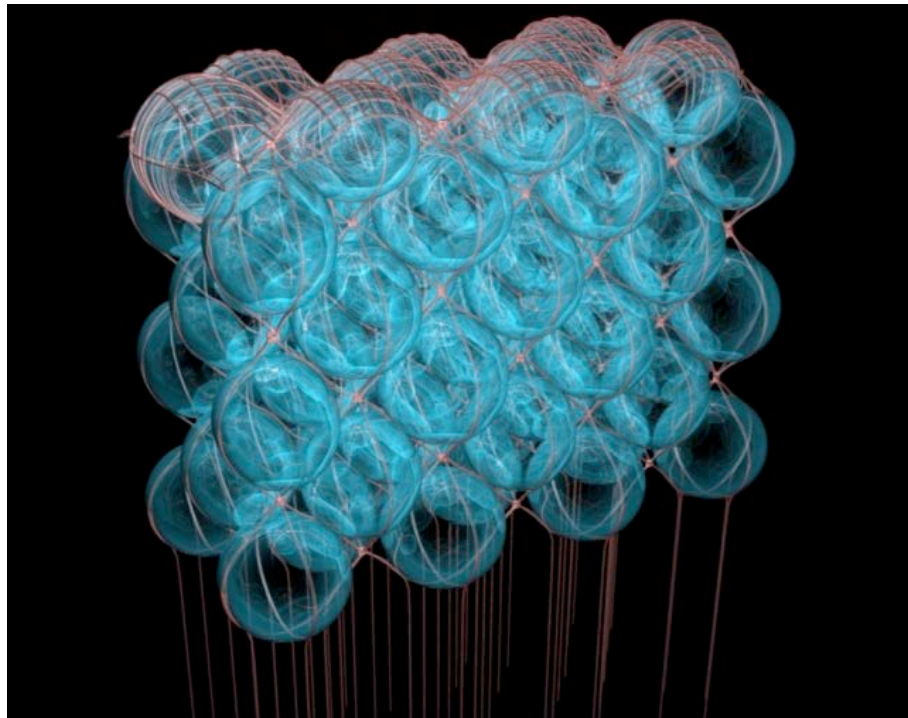
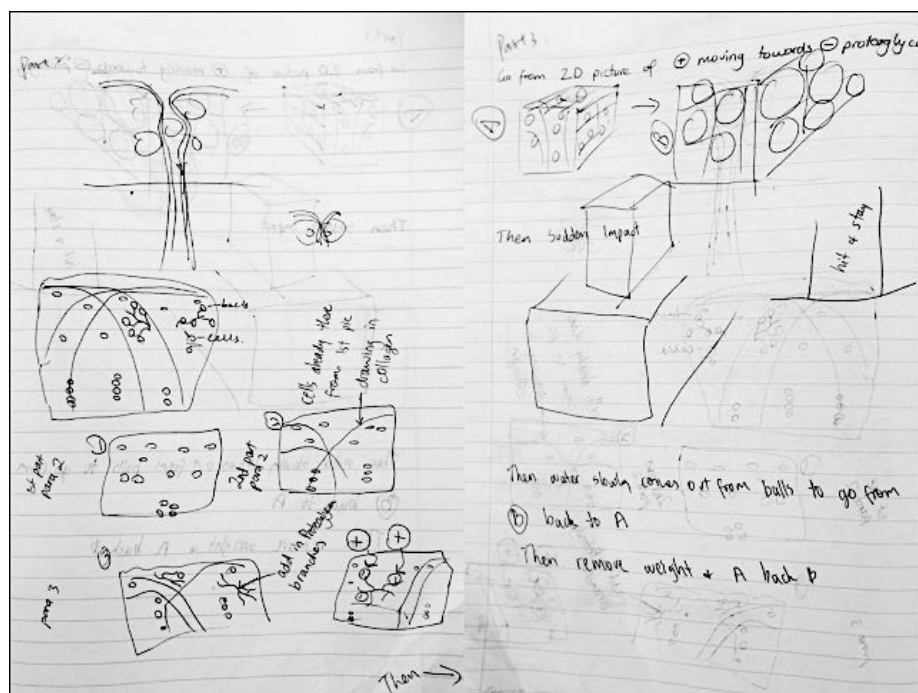


Figure 3: 3D visualisation model of human cartilage in Pre-visualisation phase.

Once a script had been agreed upon by all parties a detailed storyboard was developed to further facilitate the planning and communication across the research team.



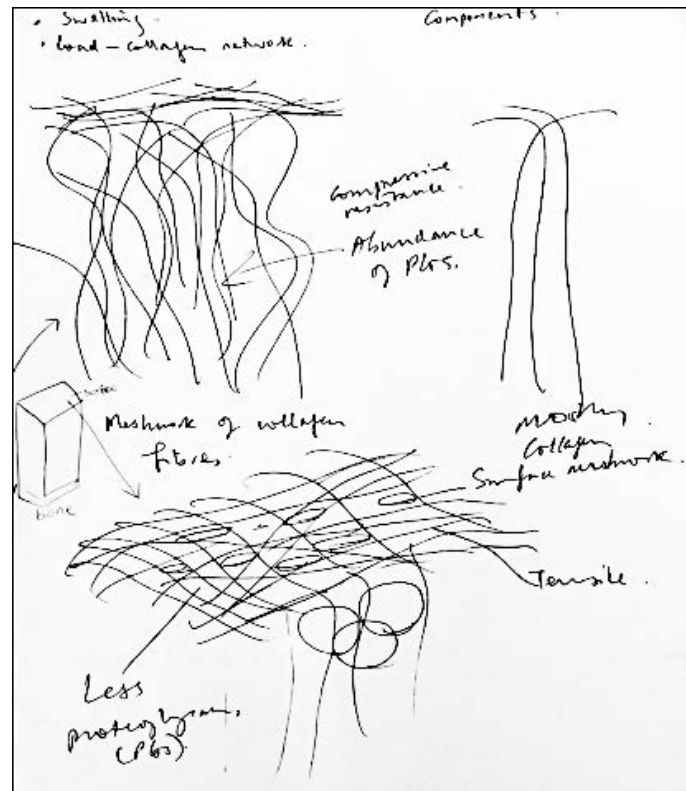


Figure 4: Storyboard design with Professor Kunle and Hayley Moody.

Several techniques common to animation practice were used to develop the final animated outcome. This included 3D polygon modelling, animation, surfacing, lighting and rendering and post rendered editing in a non-linear video editor. The final animated film was then synchronised with the recorded voice over which was a direct reading of the original script prepared for the project.

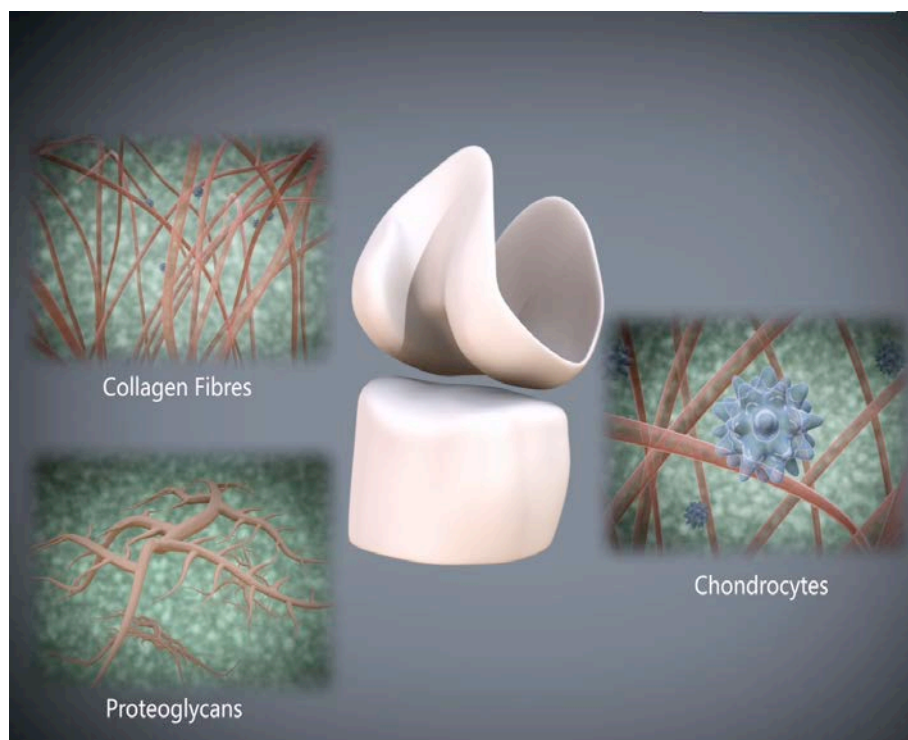


Figure 5: 3D visualisation of human cartilage component.

4 RESULT

The final animated film resulting from this research can be viewed online at the following address:

Vimeo address: <https://vimeo.com/57500732>

User name: AndyZhengQUT

Video Password: andyzhengqut

5 CONCLUSION

In as little as four and half minutes, this 3D medical visualisation communicates a large amount of information about human cartilage to its audience in an engaging way. It introduces the complex structure of human cartilage and explains the function of each component of this tissue. It also outlines the major causes of osteoarthritis. Osteoarthritis is a disease that affects many people over the age of 45. The results of this project could be applied in many domains such as surgical training, education for medical students and communication with patients etc. Osteoarthritis is a complex disease. There are many symptoms and treatment methods yet to be presented in 3D visualisation. The work is ongoing with the aim of making further improvements to the animation. Future updates will be provided at the website mentioned above.

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